Hawaiian Electric

2021 System Stability Study IGP TAP Review

Transmission Planning Department

January 21, 2022

Agenda

- Addressing TAP feedback from 2021 Dec meeting
- Summary of “System Scan” PSCAD study results for major islands
- Discussions

Addressing TAP Feedback from 2021 Dec Meeting

Dispatch Scenarios

2021 System Stability Study

- Study objectives:
  - Address system level near term needs (five/Six years) since commission of Stage 2 IPP projects.
  - Preparation for IGP-System Security Study.

June 2021

- Kick-off study
- Review resource planning scenarios
- Determine study assumptions, scope and study dispatch scenarios

September 2021

- First milestone review – steady state analysis
- Kickoff dynamic study

December 2021

- Second milestone review
  - System dynamic study results (with starting point assumptions)
  - Sensitivity study plan ★
    - Synchronous condenser study
    - DER MC study
    - Frequency response resource review
    - GFM Oscillation study

March 2022

- Fina study review
  - Sensitivity study results
  - Final conclusions and recommendations

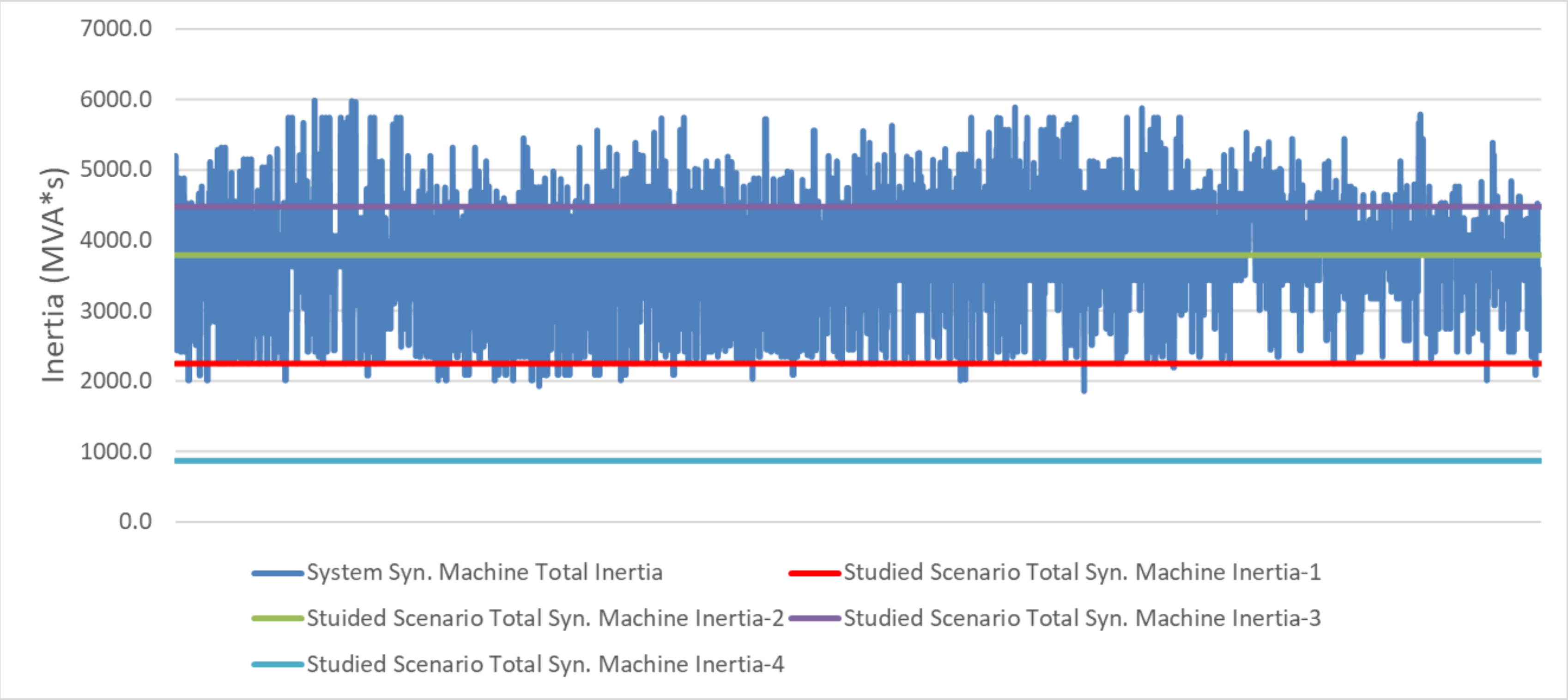
Studied Dispatch Scenarios – O`ahu Thermal Generation

- Statistics of thermal generation (MW) in 2028 between 11-13 hr and 18-20 hr.

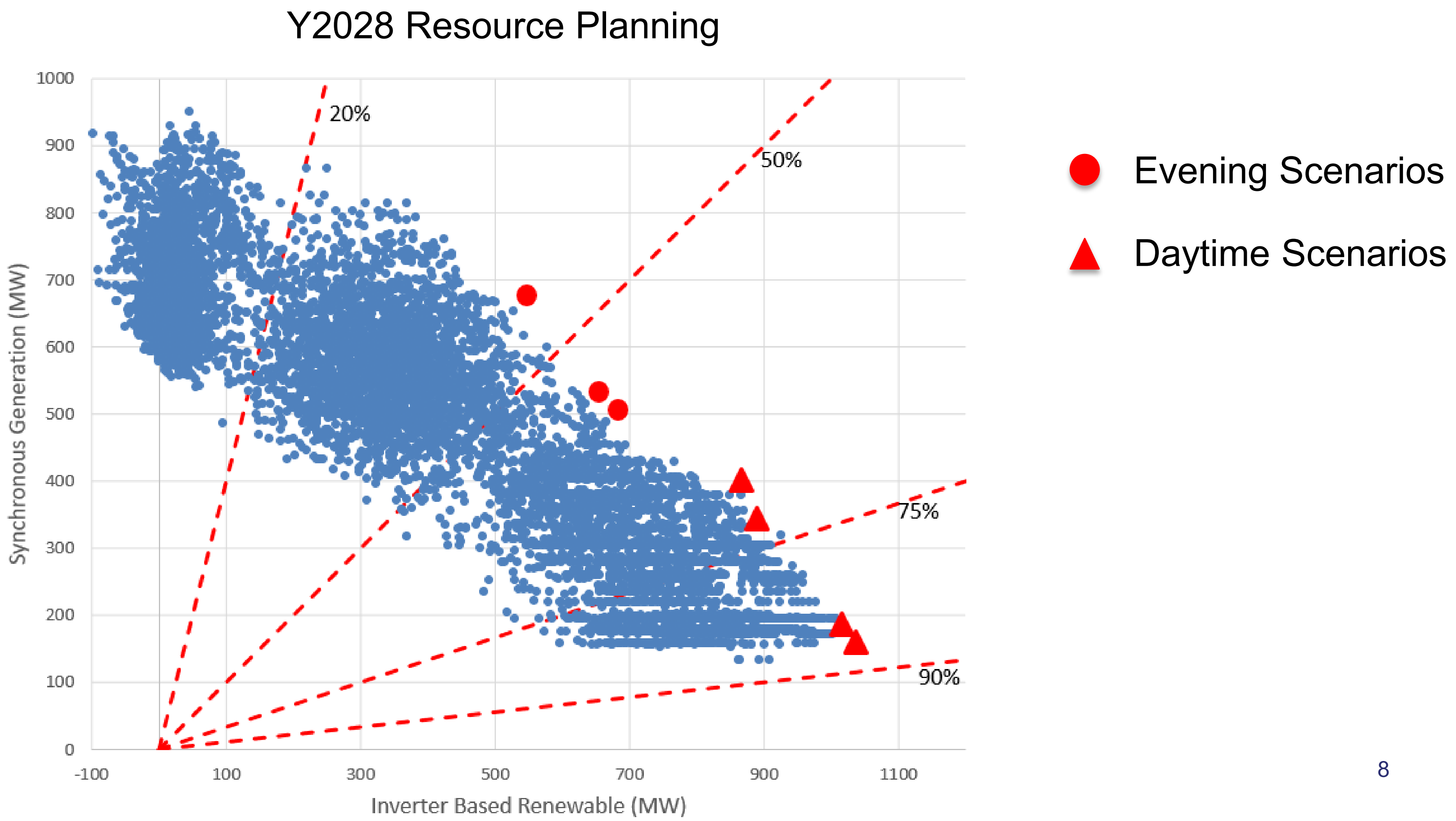
Thermal generation Daytime Scenario
- High inverter based Renewable
- Median inverter based Renewable
- Low inverter based Renewable

Thermal generation evening scenario
- High inverter based renewable
- Low inverter based renewable

Studied Dispatch Scenarios – O`ahu System Physical Inertia (MVA*s)



Studied Dispatch Scenarios – O`ahu Renewable Generation



Studied Dispatch Scenarios – O`ahu

Studied Dispatches

2028 Cases	Synchronous Machines (MW)				Centralized Renewable IPPs-GFL		Centralized Renewable IPPs-GFM		DER		System Demand (MW)
	Generation (MW)	Inertia (MVA*s)	Up-Reg (MW)	Total MVA	Generation (MW)	Total MW	Generation (MW)	Total MW	Geneartion (MW)	Installed Capacity (MW)	
DP-HD-HW											
DP-HD-LW											
DP-MaxD-LW-S											
DP-LD-HW											
DP-LD-LW											
EP-HD-HW											
EP-HD-LW											
EP-LD-LW											

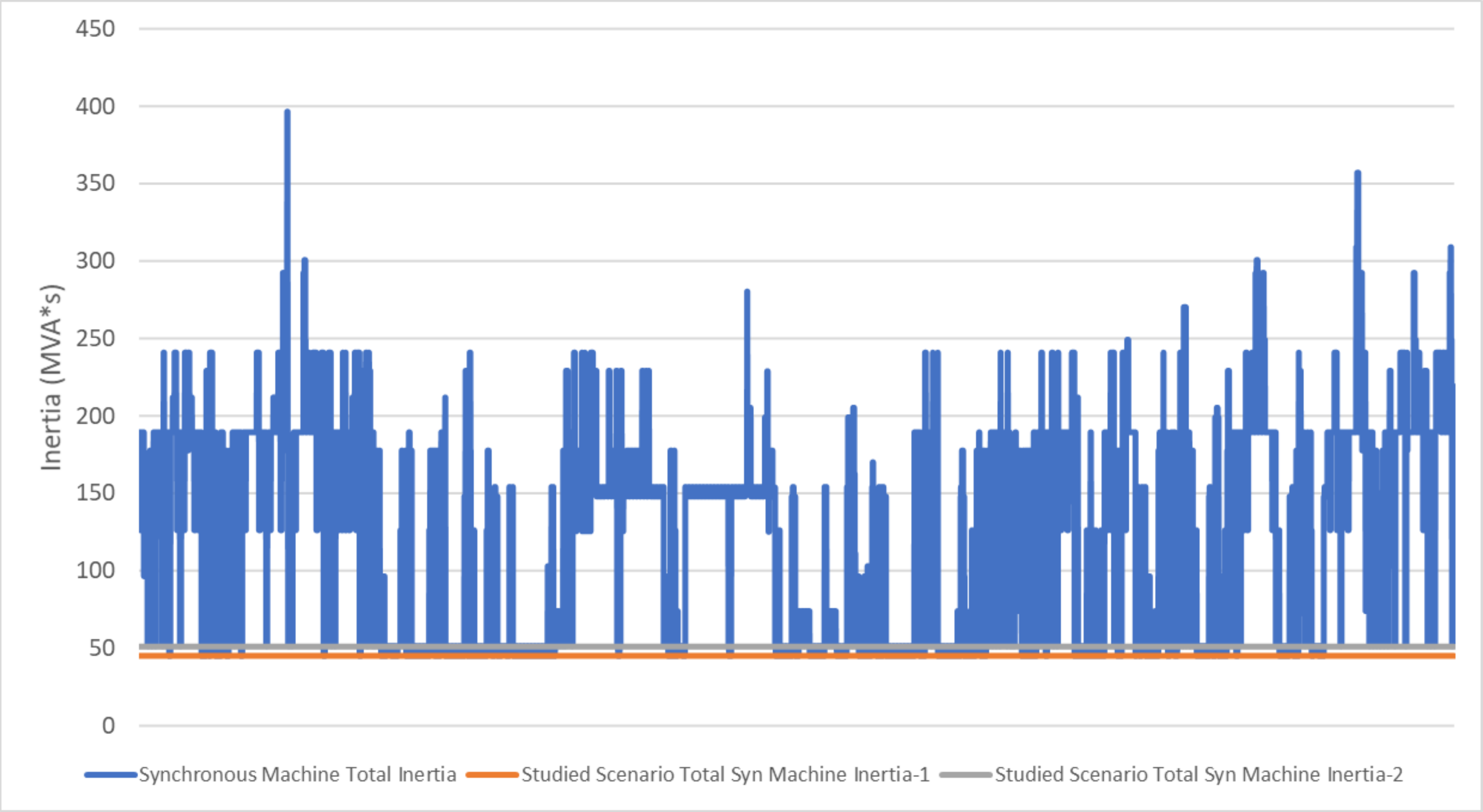
Studied Dispatch Scenarios – Maui Island Thermal Generation

- Statistics of thermal generation (MW) in 2028 between 11-13 hr and 18-20 hr.

Thermal generation Daytime Scenario
- High Renewable
- Low Renewable

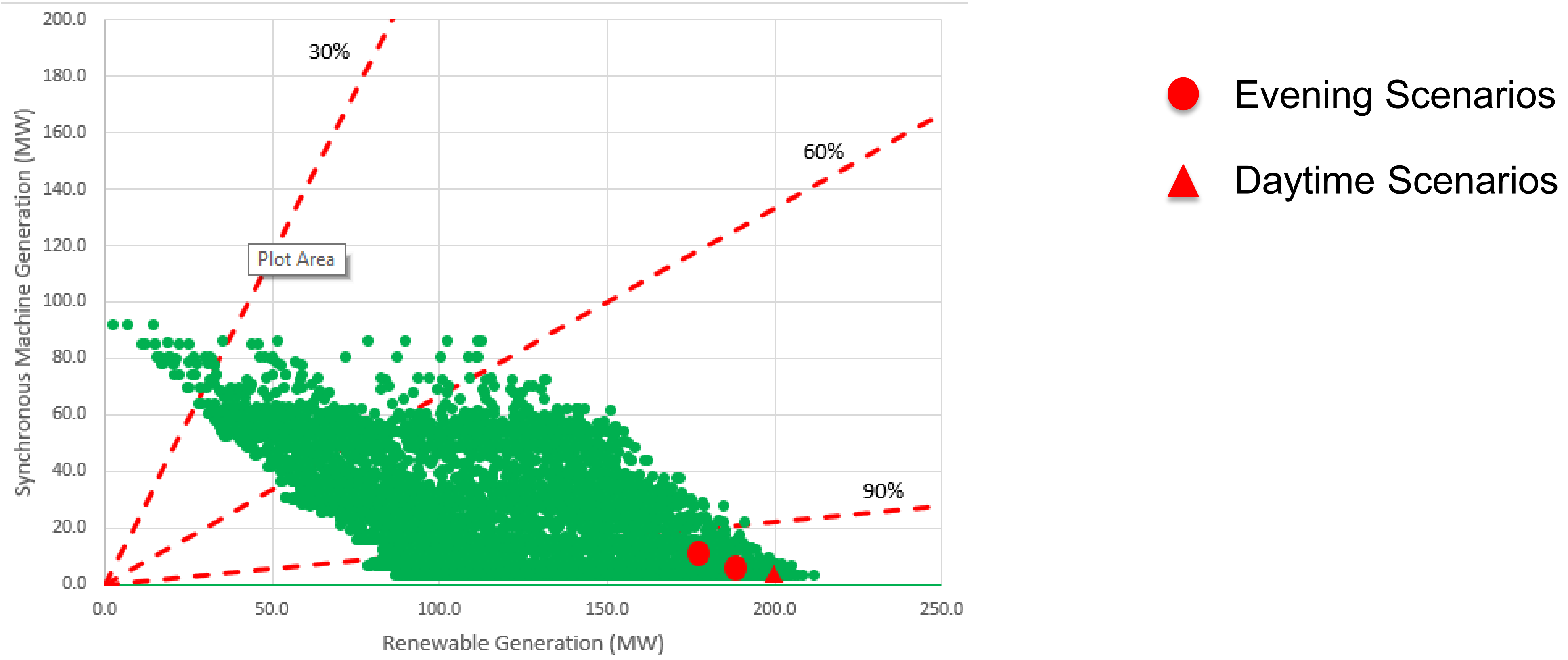
Thermal generation evening scenario
- High renewable
- Low renewable

Studied Dispatch Scenarios – Maui Island System Physical Inertia (MVA*s)



Studied Dispatch Scenarios – Maui Island Renewable Generation

Y2028 Resource Planning



Studied Dispatch Scenarios – Maui Island

Studied Dispatches

2028 Cases	Synchronous Machines (MW)				Centralized Renewable IPPs-GFL		Centralized Renewable IPPs-GFM		DER		System Demand (MW)
	Generation (MW)	Inertia* (MVA*s)	Up-Reg (MW)	Total MVA*	Generation (MW)	Total MW	Generation (MW)	Total MW	Geneartion (MW)	Installed Capacity (MW)	
DP-HD-HW											
DP-HD-LW											
DP-LD-HW											
DP-LD-LW											
EP-HW											
EP-LW											
EP-LD-LW											

*Including inertia and MVA from two units of syn. condenser.

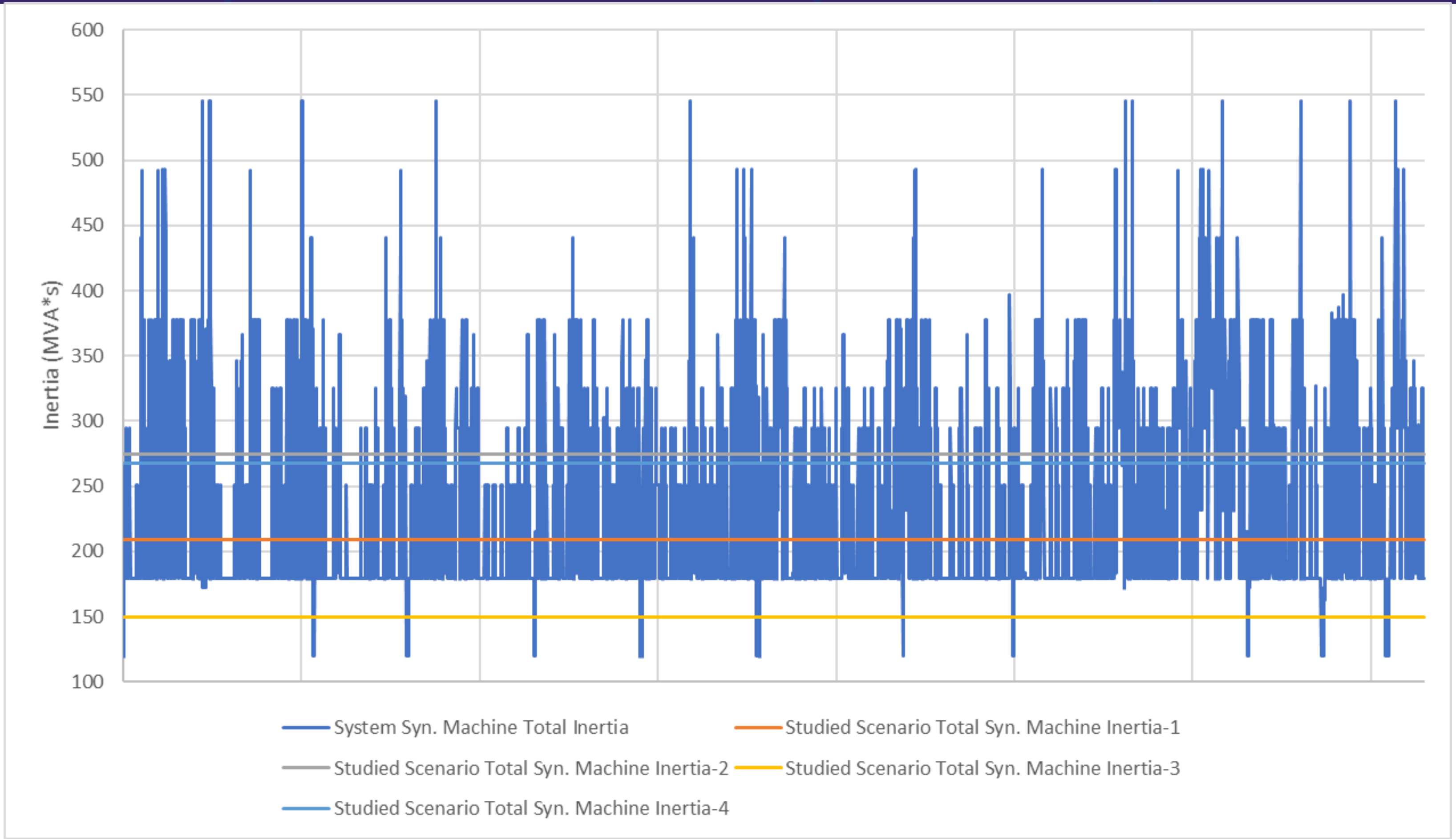
Studied Dispatch Scenarios – Hawai`i Island Thermal Generation

- Statistics of thermal generation (MW) in 2029 between 10-13 hr and 17-19 hr.

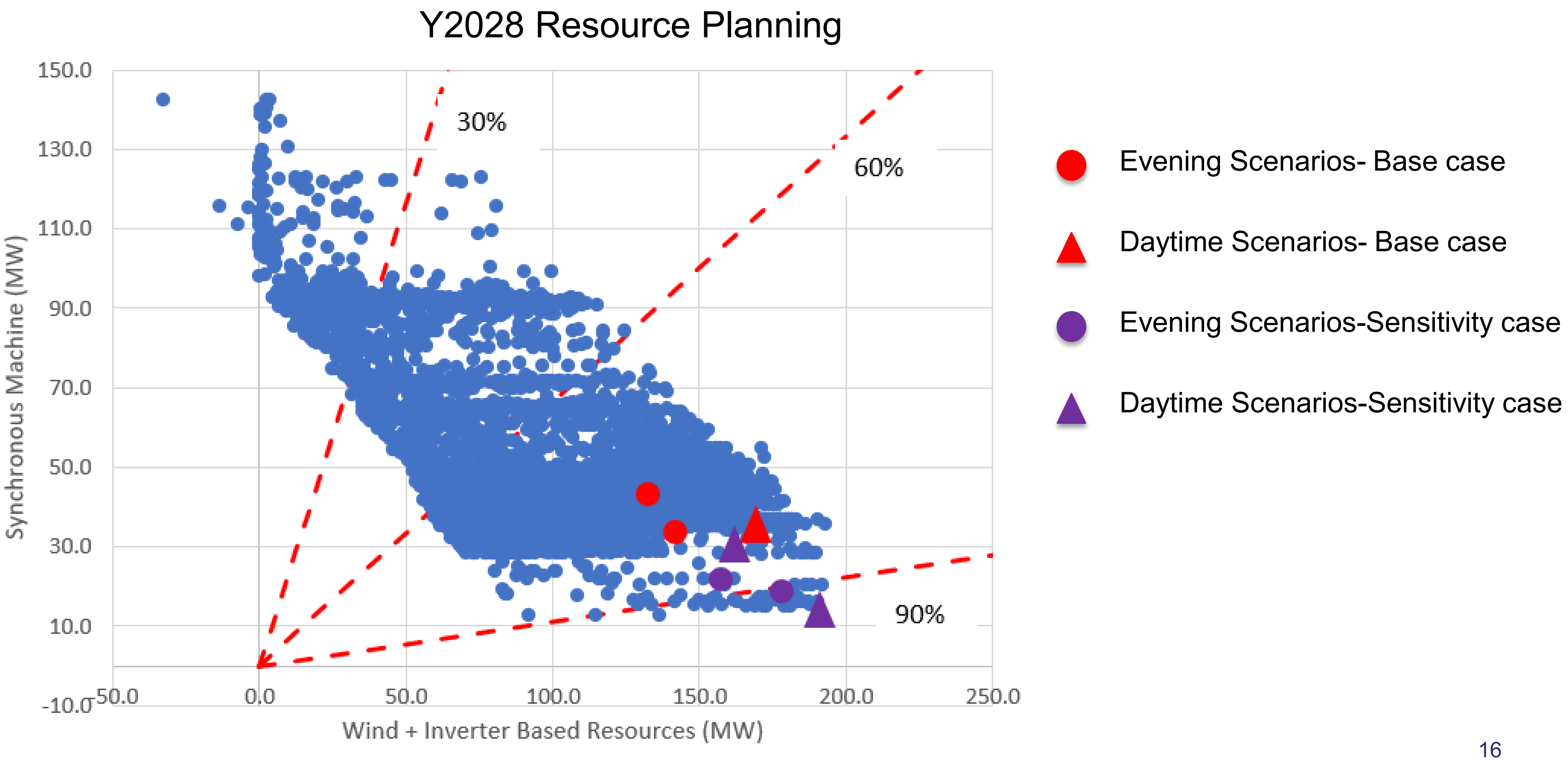
Thermal generation Daytime Scenario
- Base
- Sensitivity

Thermal generation evening scenario
- Base
- Sensitivity

Studied Dispatch Scenarios – Hawai`i Island System Physical Inertia (MVA*s)



Studied Dispatch Scenarios – Hawai`i Island Renewable Generation



Studied Dispatch Scenarios – Hawai`i Island
Studied Dispatches

Base Case

2029 Cases	Synchronous Machines (MW)				Centralized Renewable IPPs-GFL		Centralized Renewable IPPs-GFM		DER		System Demand (MW)
	Generation (MW)	Inertia* (MVA*s)	Up-Reg (MW)	Total MVA*	Generation (MW)	Total MW	Generation (MW)	Total MW	Geneartion (MW)	Installed Capacity (MW)	
DP-HD-HW											
DP-HD-LW											
DP-LD-HW											
EP-HD-HW											
EP-HD-LW											
EP-LD-LW											

Studied Dispatch Scenarios – Hawai`i Island

Studied Dispatches

Sensitivity Case

2029 Cases	Synchronous Machines (MW)				Centralized Renewable IPPs-GFL		Centralized Renewable IPPs-GFM		DER		System Demand (MW)
	Generation (MW)	Inertia* (MVA*s)	Up-Reg (MW)	Total MVA*	Generation (MW)	Total MW	Generation (MW)	Total MW	Geneartion (MW)	Installed Capacity (MW)	
DP-HD-HW											
DP-HD-LW											
DP-LD-HW											
EP-HD-HW											
EP-HD-LW											
EP-LD-LW											

DER Modeling

DER Modeling

- What characteristics does Hawaiian Electric think are important to be understood about DER?
  - From transmission planning perspective:
    - Control topology
    - Momentary cessation (entering into MC and recovery from MC)
    - Frequency response
    - ROCOF response

DER Modeling

- How Hawaiian Electric has segmented the DER fleet?
  - Grouping DER per ride-through requirements in interconnection technical requirements
    - – P1 –Legacy DER (IEEE 1547-2003)
    - – P2 – Reprogrammed DER (IEEE 1547-2003, with extended UF ride-through)
    - – P3 – Post-2016 DER (comply with Rule 14 2015 October revision)
    - – P4 – IEEE 1547-2018 certified DER

DER Modeling

- How Hawaiian Electric has characterized the behavior of each segment
  - Control – generic GFL control
  - Ride-through and tripping – Hawaiian Electric characterizes each group of DER per technical standard minimum requirements and test results.
- What approaches Hawaiian Electric thinks are reasonable & manageable for reducing the remaining uncertainty in DER behavior.
  - Using study to inform and improve interconnection technical standard
  - Using interconnection technical standard to inform DER modeling.

DER Modeling

DER Momentary Cessation (MC)

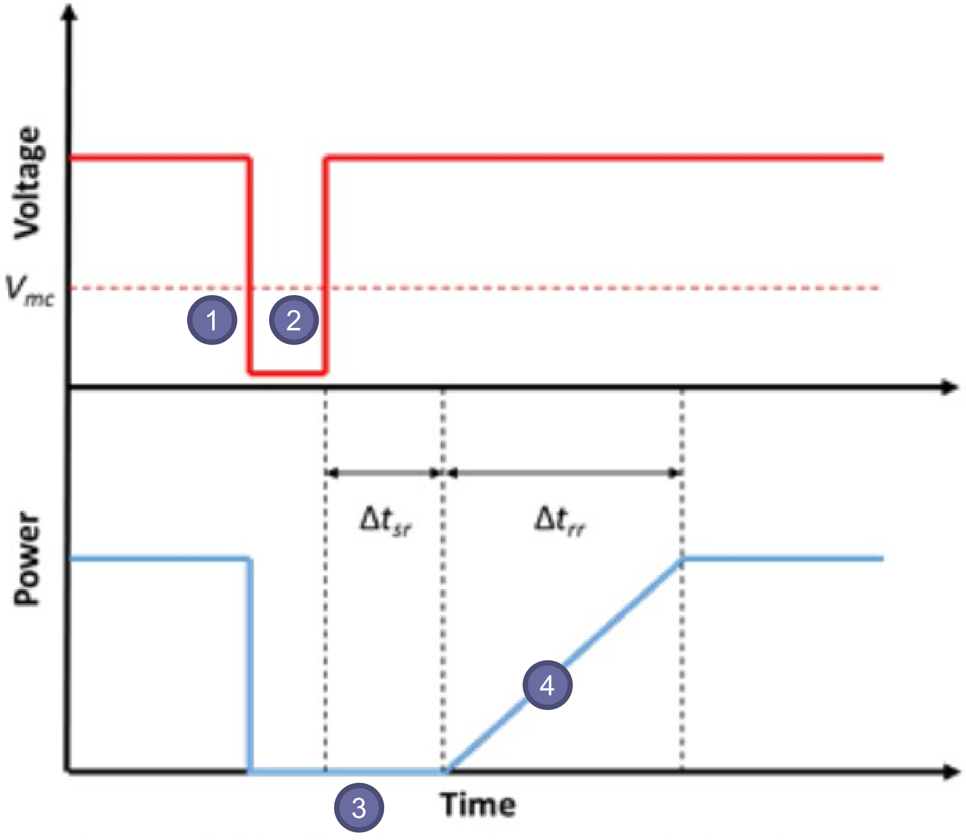


Figure 1: Illustration of Momentary Cessation

Credit: NERC

DER Type	① UV Block Limit (Vmc, PU)	② UV Unblock Limit (Vmc, PU)	③ Recovery Delay* (Δtsr, s)	④ Recovery Ramp Rate (during Δtrr, pu/s)
P1	0.45	0.45	0.033	2.2
P2	0.45	0.45	0.033	2.2
P3	0.5	0.5	0.033	2.2

*"Recovery Delay" means from the point voltage recovers above the UV unblock limit to when DER inverter active current starts to recover.

Negative Sequence Voltage Resulting from DER Tripping on One Phase

0% Syn Generation Scenario

0% Syn Generation Scenario

- No 0% Syn. Generation scenario per 2028/2029 resource planning for major islands.
- 0% Syn. Generation scenarios are studied for Molokai and Lanai.
- Per resource planning, it is unlikely to have 0% Syn. Generation scenario for O`ahu island; but it is worth to try N-1-1 for Hawai`i and Maui island to create 0% Syn. Generation scenarios for the study.

“System Scan” with Starting Point Assumptions PSCAD Study Results

PSCAD Study Scenarios
of PSCAD Simulation Cases

Planning Event	Description	O`ahu	Maui Island	Hawai`i
P1	3PH Fault w/ Loss of Transmission Line (w/ Reclosing)	11	8	1
	3PH Fault w/ Loss of Generator	0	0	0
	Loss of Generator (No Fault)	0	0	0
P2	3PH Bus Fault	5	0	2
P3	Select Cases (Loss of generator with system adjustments) - P1 Analysis	0	0	1
P4	SLG Fault with Breaker Failure (Loss of Multiple Elements)	13	5	9
P5	3PH Fault w/ Delayed Clearing (Loss of Non-Redundant Component of Protection System)	15/16	21	19

*In Progress

PSCAD Study Scenarios
of PSCAD Simulation Cases – O`ahu

Planning Event	Description	DP-HD-HW	DP-HD-LW	DP-MaxD-LW-S	DP-LD-LW	DP-LD-HW	EP-HD-HW	EP-HD-LW	EP-LD-LW
P1	3PH Fault w/ Loss of Transmission Line (w/ Reclosing)	0	0	10	0	0	0	0	1
	3PH Fault w/ Loss of Generator	0	0	0	0	0	0	0	0
	Loss of Generator (No Fault)	0	0	0	0	0	0	0	0
P2	3PH Bus Fault	0	0	6	0	0	0	0	0
P3	Select Cases (Loss of generator with system adjustments) - P1 Analysis	0	0	0	0	0	0	0	0
P4	SLG Fault with Breaker Failure (Loss of Multiple Elements)	0	0	13	0	0	0	0	0
P5	3PH Fault w/ Delayed Clearing (Loss of Non-Redundant Component of Protection System)	0	15/16	0	0	0	0	0	0

*In Progress

PSCAD Study Scenarios
of PSCAD Simulation Cases – Maui Island

Planning Event	Description	DP-HD-HW	DP-HD-LW	DP-LD-LW	DP-LD-HW	EP-HW	EP-LW	EP-LD-LW
P1	3PH Fault w/ Loss of Transmission Line (w/ Reclosing)	2	2	3	0	0	0	1
	3PH Fault w/ Loss of Generator	0	0	0	0	0	0	0
	Loss of Generator (No Fault)	0	0	0	0	0	0	0
P2	3PH Bus Fault	0	0	0	0	0	0	0
P3	Select Cases (Loss of generator with system adjustments) - P1 Analysis	0	0	0	0	0	0	0
P4	SLG Fault with Breaker Failure (Loss of Multiple Elements)	1	0	3	0	1	0	0
P5	3PH Fault w/ Delayed Clearing (Loss of Non-Redundant Component of Protection System)	4	1	4	6	1	0	5

PSCAD Study Scenarios
of PSCAD Simulation Cases – Hawai`i

Base Case

Planning Event	Description	DP-HD-HW	DP-HD-LW	DP-LD-HW	EP-HD-HW	EP-HD-LW	EP-LD-LW
P1	3PH Fault w/ Loss of Transmission Line (w/ Reclosing)	0	1	0	0	0	0
	3PH Fault w/ Loss of Generator	0	0	0	0	0	0
	Loss of Generator (No Fault)	0	0	0	0	0	0
P2	3PH Bus Fault	0	1	0	0	0	0
P3	Select Cases (Loss of generator with system adjustments) - P1 Analysis	N/A	N/A	N/A	N/A	N/A	N/A
P4	SLG Fault with Breaker Failure (Loss of Multiple Elements)	0	3	2	0	0	0
P5	3PH Fault w/ Delayed Clearing (Loss of Non-Redundant Component of Protection System)	0	6	6	0	0	0

PSCAD Study Scenarios
of PSCAD Simulation Cases – Hawai`i

Sensitivity Case

Planning Event	Description	DP-HD-HW	DP-HD-LW	DP-LD-HW	EP-HD-HW	EP-HD-LW	EP-LD-LW
P1	3PH Fault w/ Loss of Transmission Line (w/ Reclosing)	N/A	N/A	N/A	N/A	N/A	N/A
	3PH Fault w/ Loss of Generator	N/A	N/A	N/A	N/A	N/A	N/A
	Loss of Generator (No Fault)	N/A	N/A	N/A	N/A	N/A	N/A
P2	3PH Bus Fault	0	1	0	0	0	0
P3	Select Cases (Loss of generator with system adjustments) - P1 Analysis	0	1	0	0	0	0
P4	SLG Fault with Breaker Failure (Loss of Multiple Elements)	0	4	0	0	0	0
P5	3PH Fault w/ Delayed Clearing (Loss of Non-Redundant Component of Protection System)	0	7	0	0	0	0

O`ahu PSCAD Results Summary

- Most cases are stable, and no UFLS observed.
  - GFM IPP projects response are critical
  - UFLS effectiveness is not reviewed from these PSCAD results.

PSCAD Results Example – O`ahu P1 Events

O`ahu PSCAD Results Summary

- DER MC and tripping
  - Whole island DER MC observed in many planning events
  - Large amount of DER tripping observed in P4 and P5 events

O`ahu PSCAD Results Summary

- Frequency measurement and ROCOF calculation.

O`ahu PSCAD Results Summary

- IPP project tripping due to AC instantaneous overvoltage
- Unstable case observed in P5. These unstable cases are known unstable cases from previous studies and have already addressed by fast speed protection.

Maui Island PSCAD Results Summary

- All cases are stable.
- No UFLS observed in simulation time window
  - One case will likely have UFLS if simulation time is extended.
  - GFM IPP projects response is critical.

Maui Island PSCAD Results Summary

- DER MC and tripping
  - Whole island DER MC observed in many planning events
  - Large amount of DER tripping observed in P4 and P5 events
  - Unbalanced tripping of DER causes unbalanced current/power output in synchronous machines and some IPP plants

Maui Island PSCAD Results Summary

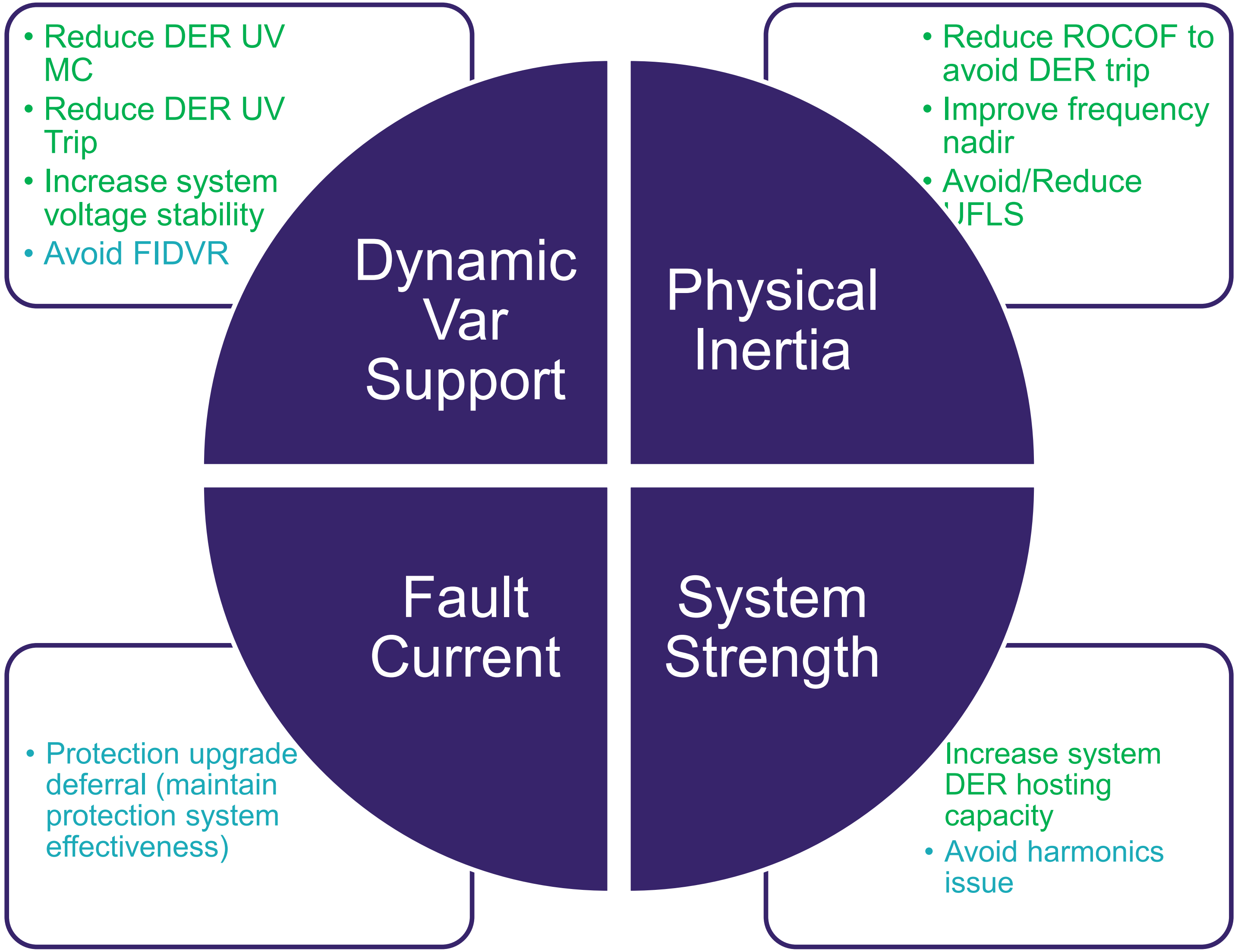
- IPP tripping
  - Both existing wind plant and IPP trips after fault being cleared in a few cases.
  - Need investigate reason of tripping.
- IPP oscillation
  - Oscillation in wind plant after fault being cleared
  - Oscillation from a few IPP projects.

Hawai`i PSCAD Results Summary

- UFLS – no planning criteria violation due to strong response from GFM projects.
- Unstable case – Hydro units show instability in a few cases in delayed clearing of 3Ph fault, no system wide instability.
- System voltage during fault
- DER MC and Tripping
  - Whole system wide DER MC in a few cases
  - DER trip in delayed clearing fault case
- ROCOF
  - Well beyond 3Hz/s in many 3Ph fault related cases.

Synchronous Condenser Sensitivity Study

Synchronous Condenser Justification



Note:

1. All these benefits overlap with benefits of firm generation
2. Dynamic var support benefit is locational sensitive.
3. Need consider N-1 scenario

Next Steps

- DER MC sensitivity study
- Frequency response resource review sensitivity study
- Preparing study report.

Questions for Discussion with TAP

Questions for Discussion

- Any suggestion/comment for handling frequency measurement modeling in planning study?
  - Current proposal:
    - Putting UFLS relay frequency measurement with high priority than DER frequency measurement
    - Identify DER frequency measurement and ROCOF ride-through via surveying inverter OEM and inverter testing.
- Any suggestion/comment for synchronous condenser study plan?

Mahalo

Questions?